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# Effects of paddock management on vegetation, nutrient accumulation, and internal parasites in laying hens

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**Primary Audience:** Researchers, Extension Specialists, Production Managers, Egg Producers

## SUMMARY

Management of paddocks for free-range layers requires an effort from farmers to minimize the adverse effects of these systems on animal health (e.g., parasites) and environment (e.g., nutrient accumulation and leaching). In this study, we report results from 2 on-farm experiments conducted to investigate (1) the effects of rotational versus continuous use of the paddocks and (2) the effects of wood chips in the area close to the pop holes (openings to the paddock) with regard to turf quality, nutrient load in the soil, and parasite infections. Rotational use of the hen paddocks led to a lower proportion of bare soil close to the house, but not in more distant regions. Covering the area in front of the house with wood chips did not reduce bare areas. Nitrogen and phosphorous contents in soil were similar in permanently and rotationally used paddocks; they were usually higher close to the house than in distant regions. Neither nutrient accumulated over the observation period. There was no significant effect of the 2 management regimens on worm burdens (*Ascaridia galli*, *Heterakis gallinarum*, *Capillaria* spp.) at the end of the laying period. Fecal egg counts were significantly reduced on rotationally used paddocks and (in 3 of 4 cases) on paddocks with wood chips in the area close to the pop holes compared with unmanaged paddocks. Based on the positive effects on turf quality, manageability, and helminth egg excretion, we recommend rotational paddock management and a permanently used, small all-weather run covered with wood chips or gravel for free-range layer flocks.

**Key words:** laying hen, outdoor area, management, nutrient accumulation, internal parasite, *Ascaridia galli*, *Heterakis gallinarum*

2013 J. Appl. Poult. Res. 22:334–343
http://dx.doi.org/10.3382/japr.2012-00586

## DESCRIPTION OF PROBLEM

Free-range systems for laying hens have become more numerous in recent years, not only due to the emerging number of organic farms but also because of conventional farms seeking to claim the production method on labels. This development has also renewed the importance of

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helminth infections, of which the roundworms *Ascaridia galli* and *Heterakis gallinarum* are the most widespread [1]. These helminth species can cause weight depression and damage the intestinal mucosa, leading to blood loss [2] and increased effects of other diseases [3].

Management of a hen paddock is a challenging task because hens tend to remain near the henhouse, where an accumulation of droppings takes place. Consequently, this area is often bare and highly loaded with nutrients (particularly phosphorus and nitrogen) and infectious stages of helminths and coccidia. Various management strategies are recommended to prevent accumulation of nutrients in the soil and increased problems related to parasitic infections.

A series of on-farm experiments has been performed to test the effects of flock size and various management practices on the dispersal of the hens in the paddock [4, 5]. In further studies, researchers focused on the effects of mowing and paddock size on turf quality and on the infection of hens with internal parasites [6] and of litter management on litter quality and infectivity [7]. In the present paper, we report results of 2 on-farm experiments conducted to investigate (1) the effect of rotational use of the paddock versus continuous use and (2) the effect of wood chips in the area close to the pop holes (openings to the paddock) with regard to turf quality, nutrient load in the soil, and parasite infections.

## MATERIALS AND METHODS

### *Experimental Farms and Birds*

All animal-related procedures were in compliance with the Swiss animal welfare act and the animal welfare ordinance.

Experiments were conducted on 2 commercial, certified organic [8] layer farms in Switzerland. On both farms, hens were fed a mixed meal (80% organic compounds) ad libitum. Depending on performance, the compound feed was complemented by a grain mixture (wheat and maize; 15–40 g/bird per day). Birds had permanent access to a covered outdoor area (wintergarden) and, with the exception of prevailing unfavorable weather conditions, daily access to an outdoor paddock (5 m$^2$ per hen).

The first farm (**farm X**), was situated in central Switzerland at 450 m above sea level. The henhouse and paddock had been used for >5 yr before the experiment. The flock of 2,000 layers was kept in an aviary system (Globogal Voletage [9]). Groups were separated into 2 larger groups (**A** and **B**) of 1,000 hens with an additional separation in the house. During the experiment, this procedure was tolerated by the certifying bodies as an exception from the organic standards requiring a maximum group size of 500 hens.

The second farm (**farm Y**), was situated in northwestern Switzerland at 350 m above sea level. The aviary system (Hornung Harmony 3B) [9] and paddocks had been used for >5 yr before the beginning of the experiment. The flock of 2,000 layers was divided into 4 groups (**A**–**D**) of 500 hens; groups were separated in the house as well as on the outdoor area according to the Swiss organic standards.

All flocks used in the experiment were of the hybrid ISA Brown [10]. Hens had been vaccinated against coccidiosis with the vaccine Paracox-8 [11] at 6 to 8-d-old in addition to the routine vaccinations against Marek's disease, infectious bronchitis, infectious bursal disease (Gumboro), and avian encephalomyelitis. No anthelmintic treatments were given during the rearing period. Pullets were reared according to organic standards and brought to the layer-house at 18 wk of age. Eighteen to 20 cockerels were integrated in each flock of 2,000 hens.

### *Experimental Setup*

On farm X, the effect of alternating use of the outdoor area on vegetation, nutrient contents of the soil, and parasite infection was investigated. Flock XA had permanent access to the whole paddock, whereas flock XB was allowed to use alternating quarters (runs) of their paddock (Figure 1). Each run was occupied by the hens for 3 to 4 wk; depending on the growth of the vegetation, quarters not occupied by the hens were mown or grazed by cattle to maintain a maximum vegetation height of about 10 cm (similar to paddock XA). The first 10 m in front of the henhouse (~140 m$^2$/1,000 hens) was used as an all-weather run and covered with wood chips. The total surface of paddocks A and B was identical (5,000 m$^2$ for 1,000 hens).

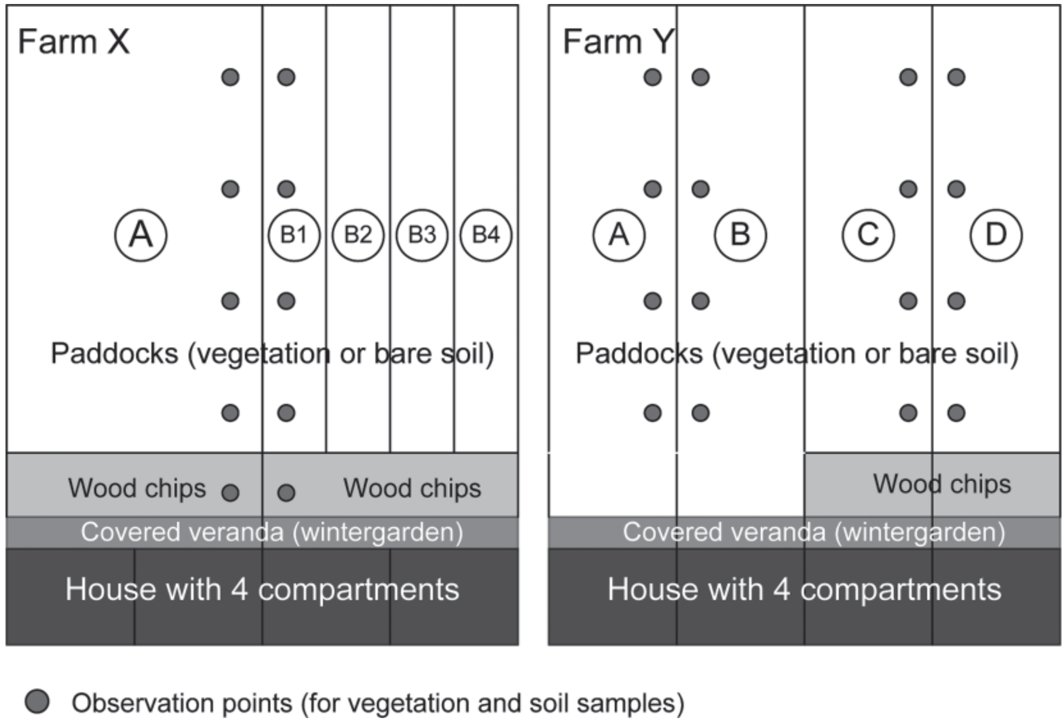


**Figure 1.** Sketch of experimental setup at farms X and Y. Capitals in circles (A–D) denote paddocks; paddock B on farm X is subdivided into 4 runs (B1–B4). Sketches are not true to scale.

The scheme was repeated during 2 vegetation periods with flock X1 (starting at around 8 mo of lay) from April to the beginning of August of the first vegetation period and flock X2 (whole laying period) from August of the first to August of the second vegetation period.

The effect of replacing woodchips on the area in front of the henhouse on turf quality and parasite infection was tested on farm Y. Four groups of layers, comprising 2 replicates (YA, YB and YC, YD) were investigated during an experimental period of approximately 12 mo and repeated with new birds in the following year: The first 10 m of the paddocks of groups YC and YD were covered with approximately 25 cm of wood chips (mainly beech, approximately 3 cm long; ~200 $m^2$/1,000 hens); the paddocks of groups YA and YB remained unaltered (Figure 1). The total surfaces of paddocks A to D were identical (2,500 $m^2$ for 500 hens).

Data were recorded during 2 laying periods with flock Y1 (ending in June of the first vegetation period) and flock Y2 (ending in June of the second vegetation period). Flock Y2 was treated with flubendazole [12] at a dosage of 10 mg/kg of BW as a feed additive over 7 d after the first vegetation period. This treatment is in accordance with organic standards in Switzerland if prescribed by a veterinarian.

***Assessment of Turf Quality***

On both farms, turf quality was assessed on 4 predefined surfaces of 1 $m^2$ along 1 compartment of each paddock. Observation points were at 18, 36, 54, and 72 m from the wintergarden (see dots in Figure 1). An observation comprised the average sward height of the plant cover, the percentage of bare soil, and botanical composition (percentage of area covered by grass, herbs, or legumes). Turf quality was assessed monthly during the vegetation period (April–October).

***Soil Analysis***

On farm X, soil samples were taken beside the observation surfaces for the assessment of turf quality and, additionally, from the area covered with chaffed wood (dots in Figure 1). Core samples were taken from 0 to 60 cm; samples from the upper (horizon 0 to 30 cm) and the lower soil layer (horizon 30 to 60 cm) were treated separately. From each sampling point, 5 individual soil samples were taken and pooled for analysis. The nutrients nitrogen (**$N_{min}$**) and phosphorus (extract of ammonium-EDTA, pH 4.65) were analyzed and kg of $N_{min}$/ha was calculated by standard techniques (NM-Ex, NM-N, and AAE10-Ex, AAE10-P) [13]. Whereas $N_{min}$ was analyzed for both horizons, phosphorus was only analyzed from the upper horizon and from chaffed wood. Samples were taken in spring (April) and in summer (July/August) of yr 1 and 2, and in autumn (October) of yr 1.

### *Parasitology*

Freshly deposited fecal samples of each group in the henhouse were collected from the dung belt at monthly intervals. Samples (>20 individual fecal pats) within each group were pooled, thoroughly mixed, and analyzed in 4 replicates using different subsamples of the pooled feces. A modified McMaster technique [14] was used to determine the number of helminth eggs per gram of feces (**EPG**) and coccidia oocysts per gram of feces (**OPG**). No differentiation was made between eggs of *A. galli* and *H. gallinarum*.

Individual worm burdens were determined in 10 randomly selected hens of each group of flocks X2, Y1, and Y2 at the end of the laying period (78 wk of age). At slaughter, the intestinal tract was removed immediately and frozen until further processing. The entire intestine was then opened in a longitudinal section, and its contents were washed on a sieve (mesh size 200µm); adult *A. galli* were removed directly from the sieve. The remainder was allowed to sediment 4 times in water to remove as much plant debris as possible before fixation in formaldehyde (5%). Helminths were then counted and determined in 20% of the gut contents under a dissecting microscope (magnification 40×). If less than 10 individuals were found in this subsample, helminths were counted in the whole sample. Occurrence of cestodes was only recorded qualitatively as within-group prevalence. Determination was performed either to the species (*A. galli*, *H. gallinarum*), genus (*Capillaria*), or class (in the case of cestodes) [15, 16].

### *Analysis of Parasitological Data*

For worm counts, generalized linear models assuming clumped data and negative binomial distribution [17, 18] were applied using the statistical software Stata /IC10.0 [19]. Fecal egg counts were analyzed according to Torgerson et al. [20].

## RESULTS AND DISCUSSION

### *Vegetation*

Descriptive results of vegetation scoring are presented in Figure 2 using pooled data per observation point (data of 2 vegetation periods on farm X; data of 1 vegetation period and 2 replicates on farm Y). Rotational use of runs led to a reduction of the bare area close to the house (Figure 2); over 90% of the soil was bare in the first quarter and almost 40% in the middle of the permanently used paddock. This proportion was reduced to ≤22% in the area close to the house of runs used alternately, the bare soil being mainly replaced by grass cover. Where vegetation was present, its average height was between 9 and 12 cm in all the quarters except for paddock A at 36 m from the henhouse, where vegetation height was 4 cm (data not shown). The results from farm Y were similar (Figure 2), with the exception that 10 to 20% of the soil was bare in the distant quarters of the paddocks as well. Vegetation height was between 8 and 15 cm in the quarters with >20% vegetation cover, whereas it was only 5 cm in paddocks A and B at 36 m from the henhouse (data not shown).

### *Soil Analysis*

Soil type on farm X was defined as medium to heavy brown soil (pH 7, 1–3% soil carbon). Descriptive results of the soil analysis are presented in Table 1. Nitrogen (mg/ha) contents were similar in both paddocks and all the observation points. Nitrogen contents increased from spring to summer in both years through manure deposition of the hens and soil mineralization (2–2.5 times, respectively). At the summer sam-

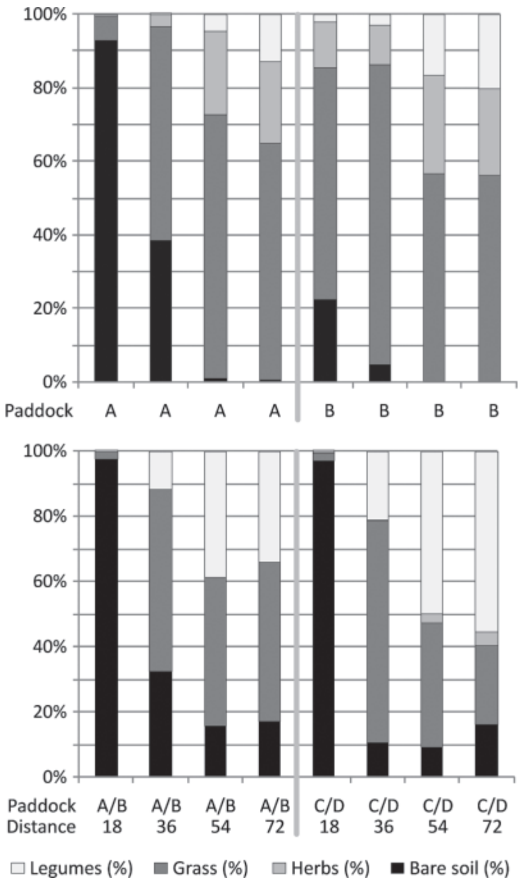


**Figure 2.** Sward composition of farm X (above) and farm Y (below). Graphs show the average per observation point (18, 36, 54, and 72 m from the henhouse) of 14 observations in 2 vegetation periods for farm X and 8 observations in 1 vegetation period for farm Y.

pling in yr 1, $N_{min}$ contents were high in paddock A compared with paddock B. The $N_{min}$ content decreased from summer to autumn of year 1 and over winter to spring of yr 2. There were no differences in $N_{min}$ in deeper soil layers (30–60 cm) between paddocks A and B in yr 1 (data not shown). The $N_{min}$ values also did not increase in the deeper soil horizon in spring of yr 2, as would have been expected due to leaching over winter. After winter, there were very low $N_{min}$ values in the deeper layer of paddock B (<10 kg of $N_{min}$/ha). In contrast, $N_{min}$ values were higher in paddock A (up to 30 kg of $N_{min}$/ha), indicating that plant cover in the rotationally used paddock B reduced leaching over the winter.

Phosphorus (**$PO_4$-P**; mg/kg of soil DM) content in the soil close to the house (18m) increased 2 to 10 times in the permanently used paddock A compared with the rotationally used paddock B in yr 1, whereas values were similar in yr 2. Values were also similar in remote regions of the paddocks.

Table 2 presents the nutrient analysis in and under the chaffed wood near the henhouse. In general, $N_{min}$ and PO-$P_4$ contents of the soil under the wood chips were within the range of the values obtained for soil samples from the paddock (Table 1), whereas nutrient content of the chips was higher. Chaffed wood of the permanently used paddocks contained 1.5 to 3 times more $N_{min}$ than the wood of the rotationally used runs. The $N_{min}$ values in soil under wood chips were similar for both management regimens. In soil under wood chips, PO-$P_4$ contents increased from spring the first year (classified as just normal to surplus) [21] to summer of yr 2 (classified as enriched). In contrast, PO-$P_4$ content 18 to 72 m from henhouses remained constant.

### *Parasitology*

In flock X1, eggs of all helminth species were only present at very low numbers (<50 EPG). Low values (e.g., values <200 EPG in pigs [22, 23]; <100 EPG in poultry [6]) are often regarded as false positive due to ingestion and gut passage of helminth eggs that are not yet infective; data of flock X1 are therefore not presented. Figure 3 shows the results of EPG in flocks X2, Y1, and Y2.

In all flocks (with the exception of flocks Y1 in paddocks with chips), hens started to excrete helminth eggs in October after installation. Flock X2 had a peak *Ascaridia* or *Heterakis* egg excretion in December; whereas the second untreated flock, Y1, reached the peak not before spring. *Ascaridia* or *Heterakis* egg excretion declined in both untreated flocks and reached values below 100 EPG at slaughter in July. In the treated flock, Y2, *Ascaridia* or *Heterakis* egg counts were reduced to 0 and, after 2 samples without helminth eggs in December and January, increased toward spring without an obvious reduction before slaughter. In flock X2, an overall reduction of *Heterakis* or *Ascaridia* fecal egg output was observed in group B compared with A ($P < 0.001$), but the magnitude of the effect is only 9.9%. In both groups, an

**Table 1.** Nitrogen ($N_{min}$) and phosphorus ($PO_4$-P) in soils of farm X (descriptive data)

| | | $N_{min}$ (kg/ha) | | | | | | | | $PO_4$-P (mg/kg of soil DM) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Paddock A (permanent use) observation points (m) | | | | Paddock B (rotational use) observation points (m) | | | | Paddock A (permanent use) observation points (m) | | | | Paddock B (rotational use) observation points (m) | | | |
| Year | Season | 18 | 36 | 54 | 72 | 18 | 36 | 54 | 72 | 18 | 36 | 54 | 72 | 18 | 36 | 54 | 72 |
| 1 | Spring | 137.4 | 87.5 | 59.6 | 96.5 | 154.2 | 105.6 | 63.2 | 83.3 | 479.1 | 11.9 | 79.2 | 15.9 | 67.6 | 34.5 | 73.1 | 31.8 |
| | Summer | 603.8 | 324.2 | 233.9 | 172.1 | 221.0 | 165.4 | 166.4 | 216.7 | 120.8 | 20.8 | 76.6 | 51.4 | 28.7 | 31.4 | 122.7 | 61.4 |
| | Autumn | 266.3 | 94.5 | 122.3 | 147.3 | 170.9 | 130.8 | 167.5 | 195.4 | 56.6 | 13.6 | 73.6 | 26.3 | 29.2 | 16.9 | 98.7 | 43.1 |
| 2 | Spring | 57.1 | 32.1 | 21.6 | 49.3 | 32.0 | 18.9 | 46.8 | 85.4 | 47.5 | 22.3 | 57.8 | 78.2 | 35.5 | 17.6 | 31.2 | 95.6 |
| | Summer | 164.4 | 61.9 | 28.5 | 87.4 | 228.9 | 39.6 | 41.3 | 74.2 | 29.6 | 13.5 | 58.1 | 39.2 | 39.5 | 18.7 | 55.3 | 30.1 |

evident yet not explicable decline of fecal egg counts was noted in the December sample. In flock Y1, overall reduction of *Heterakis* or *Ascaridia* fecal egg output in paddock C was also highly significant compared with paddock A ($P < 0.0001$), with a magnitude of 31%; a highly significant reduction of 29% was also observed in paddock D compared with paddock B ($P < 0.0001$). In flock Y2, *Heterakis* or *Ascaridia* fecal egg counts were, again, significantly ($P < 0.01$) lower in paddock C than in paddock A, with a reduction of 14%; whereas paddocks B and D were not significantly different ($P > 0.05$). *Capillaria* spp. egg counts were always at a lower level than those of *Heterakis* or *Ascaridia* (<10%). In untreated flocks, peak *Capillaria* spp. egg excretions were observed about 2 to 4 mo after those of *Heterakis* or *Ascaridia*. In contrast, peak *Capillaria* spp. egg excretion took place earlier in the treated flock, Y2. Cestode eggs were not detected in the fecal samples.

*Eimeria* oocyst counts (data not shown) were at low levels, between 0 and 300 OPG, except for flock Y1, where higher values (680–5,400 OPG) were found occasionally. Table 3 summarizes the worm burdens determined in hens at slaughter. Group means of *A. galli*, *H. gallinarum*, and *Capillaria* spp. did not differ between paddock types ($P > 0.18$). Within-flock prevalence of *A. galli* and *H. gallinarum* was between 70 and 100% in all flocks, whereas it was lower (30–40%) for *Capillaria* spp. in all groups of flock Y2. Cestodes were present in all flocks, with within-flock prevalences between 20 and 66% in the single groups. Whereas average *A. galli* burdens were similar in all flocks (15–40 worms/hen), individual worm burdens varied and a maximum of 136 *A. galli* individuals was detected in a single hen. Similar counts were found in *H. gallinarum* and *Capillaria* spp.

### *Practical Impact*

Rotationally used paddocks had good vegetation cover and turf quality, mainly in front of the henhouse. Correspondingly, there was a higher plant uptake of nitrogen and lower $N_{min}$ contents in the summer sample of the rotationally used runs. In both years, however, $N_{min}$ was still frequently higher than plant demand on intensive pastures (120 kg of $N_{min}$/ha for 6 grazing cycles)

**Table 2.** Nitrogen ($N_{min}$) and phosphorus ($PO_4$-P) in chaffed wood and in soil under chips of farm X (descriptive data)

| | | | $N_{min}$ (mg/kg of DM) | | $PO_4$-P (mg/kg of DM) | |
|---|---|---|---|---|---|---|
| Year | Season | Material | Paddock A (permanent use) | Paddock B (rotational use) | Paddock A (permanent use) | Paddock B (rotational use) |
| 1 | Spring | Chips | 112.9 | 54.8 | 577.8 | 603.4 |
| | | Soil | 28.7 | 30.0 | 65.8 | 91.0 |
| | Summer | Chips | 91.0 | 30.5 | 59.6 | 450.6 |
| | | Soil | 42.9 | 30.9 | 97.3 | 63.1 |
| | Autumn | Chips | 211.7 | 148.9 | 463.0 | 397.5 |
| | | Soil | 33.2 | 51.6 | 56.5 | 113.4 |
| 2 | Spring | Chips | 123.6 | 73.7 | 136.0 | 190.86 |
| | | Soil | 3.9 | 12.7 | 160.2 | 126.1 |
| | Summer | Chips | 64.2 | 42.0 | 98.1 | 171.3 |
| | | Soil | 26.9 | 31.4 | 133.4 | 133.6 |

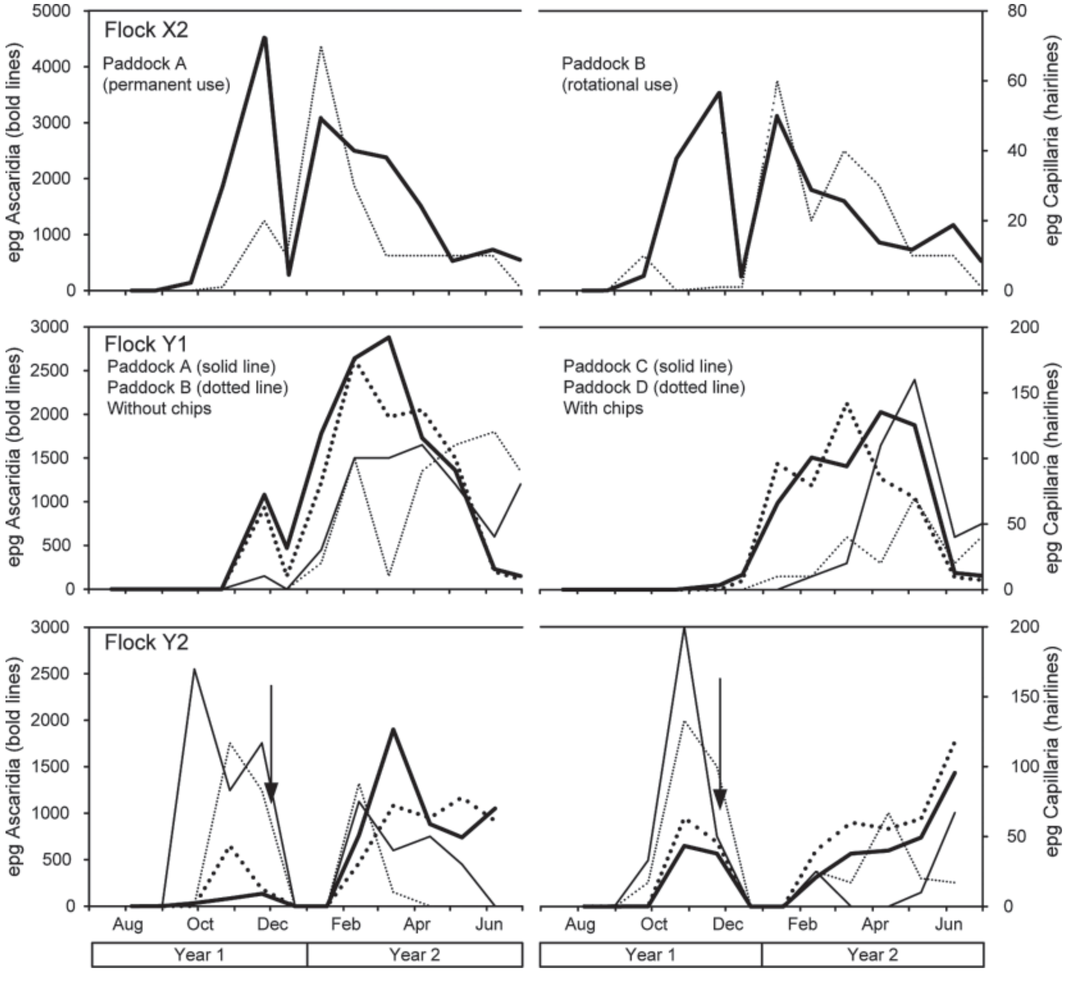


**Figure 3.** Fecal egg counts (EPG) of flocks X2, Y1, and Y2. Bold lines present EPG of *Ascaridia galli* (left y-axis); hairlines are EPG of *Capillaria* spp. (right y-axis). Flock Y2 was treated with flubendazole at the time point indicated by arrows.

**Table 3.** Worm burdens in hens detected postmortem (wk 78)

| Farm | Flock | Paddock type | Animals (n) | *Ascaridia galli** Mean (minimum–maximum) | *Ascaridia galli** Prevalence[1] (%) | *Heterakis gallinarum** Mean (minimum–maximum) | *Heterakis gallinarum** Prevalence[1] (%) | *Capillaria* spp.* Mean (minimum–maximum) | *Capillaria* spp.* Prevalence[1] (%) | Cestodes Prevalence[1] (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| X | 2 | A (permanent use) | 10 | 16.2 (1–57) | 100 | 71.5 (5–355) | 100 | 24.5 (0–100) | 80 | 20 |
| | | B (rotational use) | 10 | 14.7 (0–70) | 70 | 108.5 (0–610) | 90 | 13.0 (0–65) | 80 | 30 |
| Y | 1 | A (without chips) | 10 | 22.9 (0–67) | 90 | 57.0 (0–190) | 90 | 106 (20–245) | 100 | 30 |
| | | B (without chips) | 9 | 31.3 (0–62) | 89 | 124.4 (5–670) | 100 | 113.9 (25–205) | 100 | 55 |
| | | C (with chips) | 10 | 17.2 (0–62) | 80 | 79.0 (0–205) | 90 | 136.0 (5–440) | 100 | 60 |
| | | D (with chips) | 9 | 31.1 (0–136) | 78 | 53.9 (0–258) | 89 | 79.4 (5–365) | 100 | 55 |
| | 2 | A (without chips) | 10 | 39.7 (6–113) | 100 | 103.5 (10–230) | 100 | 2.0 (0–10) | 30 | 50 |
| | | B (without chips) | 10 | 27.8 (1–99) | 100 | 123.5 (5–325) | 100 | 3.0 (0–15) | 30 | 30 |
| | | C (with chips) | 9 | 24.8 (0–58) | 89 | 88.3 (0–460) | 89 | 2.8 (0–15) | 33 | 66 |
| | | D (with chips) | 10 | 30.9 (2–106) | 100 | 68.5 (0–255) | 70 | 6.0 (0–40) | 40 | 50 |

[1]Within-flock prevalence.
*No significant differences between flocks and paddock types ($P > 0.18$).

[21] or even on intensively managed turf grass (150–250 kg of $N_{min}$/ha) [24].

Phosphorus is only a little mobile in soil, especially in the presence of lime; the biggest losses are caused through soil surface erosion (runoff). Therefore, accumulation was expected to take place in the flat paddocks of farm X. However, in both paddock types A and B, no accumulation was observed and the phosphorus content of soil reached medium values for arable land and pastures, where no adjusting of fertilization strategies is recommended [21].

Rotational use enables better management (e.g., mowing) of the paddock, but is only possible if group size is at least 1,000 hens; otherwise, runs are too narrow for mechanical work. Separations of runs should not be extended to the houses, but to a permanently used all-weather run, as established on farm X (Figure 1). This area should be covered with material that allows the hens to scratch and dust bathe. Also, it should be possible to clean or replace the material for optimal hygiene and reduced nutrient leaching. Inorganic and organic materials, such as pea gravel or wood chips, fulfill these requirements. Chaffed wood was used in the present experiment because this material is usually easily available and because it can be removed and composted after use. With this measure, 0.03 to 0.2 kg of $N_{min}$ and 0.06 to 0.6 kg available PO-$P_4$/t of chips (DM) would have been removed from a heavily loaded area and made available for use in crop production in the present field trial.

The course of *Ascaridia* or *Heterakis* egg excretion in flocks X2 and Y1 exhibited the typical pattern for untreated flocks [25], characterized by a sharp increase within 2 to 3 mo and a decline to low levels afterward. This reduction is more pronounced compared with results from organic farms in Sweden [25] and is most likely due to a loss of adult worms, which could be more pronounced in hens exposed to continuous infection than it has been observed after single experimental challenge [26]. Worm numbers and fecal egg counts of flocks X2, Y1, and the treated flock, Y2, are within the range observed in layers [6] and higher than those reported from a Danish study [27] at similar stocking rates. The finding that worm burdens vary widely between animals in the same flock confirms that, based on individual differences within the same hybrid, selection for *A. galli* resistance in layers is a realistic approach [28]. It also emphasizes the importance of examining several animals for assessing the parasitological status of a flock.

Rotational use of the paddock on farm X did apparently not have any influence on the mean worm burden at the end of the observation period compared with the layers on the permanently used paddock. However, the chosen design does not allow any conclusion to be drawn on potential discrepancies of worm burdens within the trial period. Fecal egg counts were significantly lower in the rotational system, although the magnitude of the reduction was limited to 10% compared with the flocks on the permanently used paddock. A difference in this range will most likely not have any practical consequences; however, it cannot be excluded that these effects would become more pronounced after several years. A more profound effect on *Heterakis* or *Ascaridia* fecal egg output of approximately 30% ($P < 0.05$) was observed in the paddocks on farm Y, where chips were used and removed regularly compared with the paddocks without chips. The effect was lower and less or not significant in the second flock, presumably due to an overall reduction of fecal egg counts after anthelmintic treatment of flock Y2 in early winter. Based on the results of Maurer et al. [7], survival of infectious stages of helminths is reduced in organic materials, as high numbers of helminth eggs in litter corresponded with parasite-naïve tracer chickens harboring fewer helminths after exposure to litter than after exposure to soil with much lower helminth egg concentrations. Similar observations are reported by extension specialists (W. Baumann, personal communication) [29], who expect chaffed wood to reduce survival of infectious stages of helminths. The phenomenon is not completely understood, but there are indications for reduced survival of helminth eggs in ligneous litter material. As hens in large free-range flocks tend to remain inside [30] or in the vicinity of the house, the design of this area is of increasing importance with increasing flock size.

## CONCLUSIONS AND APPLICATIONS

1. Rotational use of the hen paddocks led to a low proportion of bare soil close to the house but not in the more distant regions.
2. Covering the area in front of the house with wood chips did not reduce the bare areas.
3. Nitrogen and phosphorous contents in soil were similar in permanently and rotationally used paddocks; they tended to be higher close to the house than in more distant regions.
4. During the observation period, $N_{min}$ and $PO\text{-}P_4$ contents were at high levels, but no noticeable nutrient accumulation took place.
5. There was no significant effect of the 2 management regimens on worm burdens (*A. galli*, *H. gallinarum*, *Capillaria* spp.) at the end of the laying period.
6. *Heterakis* or *Ascaridia* fecal egg counts were significantly reduced on a rotationally used paddock and (in 3 out of 4 cases) on paddocks with wood chips in the area close to the pop holes compared with unmanaged paddocks.
7. Based on the positive effects on turf quality, manageability, and helminth egg excretion, we recommend rotational paddock management and a permanently used all-weather run covered with wood chips or pea gravel for flocks with >1,000 free-range hens.

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## *Acknowledgments*

The authors thank Paul Torgerson (Section of Epidemiology, University of Zurich, Switzerland) for statistical analysis of fecal egg count data and Lucy Kohler (Institute of Parasitology, University of Zurich, Switzerland) for laboratory analysis of fecal samples. The assistance of the farm managers JakobTreichler (Baar, Switzerland) and Dieter Weber (Liestal, Switzerland) is highly acknowledged.